ACTIVITIES OF THE SHIELDING SUBCOMMITTEE OF THE ENDF/B CROSS SECTION EVALUATION WORKING GROUP*

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ABSTRACT

The Shielding Subcommittee of the Cross Section Evaluation Working Group (CSEWG) was established in 1967 to help ensure that the content of the ENDF/B cross section library was adequate for treating shielding problems.

Early work of the subcommittee concentrated on devising formats for gamma-ray interaction and production data, as well as providing programs for testing the clerical and physics consistency of the files. The Radiation Shielding Information Center (RSIC) collaborated directly with evaluators on behalf of the National Neutron Cross Section Center (NNCSC) to begin testing and adding data sets to be fed into the official ENDF/B libraries. These efforts, which were sponsored by AEC-DRDT (now ERDA-DRDD), were augmented greatly through the Defense Nuclear Agency program of establishing a working cross section library in ENDF format. The effort concentrated on evaluation and testing of materials of interest to DNA programs and providing these for inclusion in the ENDF/B library.

Shielding data testing efforts, as a part of the CSEWG Data Testing Program, are now also an integral part of the Shielding Subcommittee effort. Procedures for writing and approving the shielding benchmarks were devised by Shielding Subcommittee members. Data testing benchmark experiments have been documented and analyzed, and the most recent results for ENDF/B-IV are as reported as part of ENDF-230, "Benchmark Testing of ENDF/B-IV."

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Current and future activities of the subcommittee include (1) providing sensitivity coefficients for selected shielding experiments to aid ENDF/B-V evaluators, (2) documentation and analysis of new benchmarks for fast reactor (shielding) integral experiments, and (3) expanding formats and procedures as indicated by the needs of the newer community of ENDF/B users.

It is expected that much of the new activity of the Shielding Subcommittee will be on behalf of the controlled thermonuclear research (CTR) neutronics community in the area of new evaluations via the CTR Working Library and the documentation and analysis of new integral benchmarks for fusion sources and materials.

HISTORICAL BACKGROUND OF SHIELDING SUBCOMMITTEE ACTIVITIES

Formation of the Shielding Subcommittee

The first meeting of the Cross Section Evaluation Working Group (CSEWG) was held in June 1966. The summary of that meeting states that "One of the long range goals of the Reactor Physics Branch of the Division of Reactor Development and Technology [of the United States Atomic Energy Commission (AEC)] is the development of a set of basic nuclear data which can be used to accurately predict the behavior of neutrons in a nuclear reactor."

The second CSEWG meeting, in November 1966, included a discussion "to consider in what ways the initial accomplishments might be strengthened and what additional objectives should be attempted." A subcommittee structure was adopted to pursue the subjects of Codes and Formats, Data Testing, Normalization, Resolved Resonance Region, and cross sections for Shielding.

Initial Goals of the Shielding Subcommittee

The first version of the CSEWG reference data set, ENDF/B-I, was issued in 1967. The Shielding Subcommittee, which had its first meetings in 1967, was charged by CSEWG with several tasks, some of which were enumerated in Ref. 1, as follows:

1. Recommend additional types of data to be added to ENDF/B for shielding and specify the detailed formats for storing such data. The formats should conform as nearly as possible to the existing ENDF/B formats.

2. Examine data presently on the ENDF/B tape to determine its completeness from the point of view of shielding calculations.

3. Recommend a list of priorities for data on materials of interest to shielders, to be evaluated and translated to the ENDF/B format.

4. Recommend data check[illegible] and processing codes required for shielding data to be placed on the ENDF/B tape.

5. Recommend calculational and experimental programs for testing the shielding data.

The Subcommittee began work on the above tasks and also made additional recommendations. Among these was the recommendation for a suitably coordinated effort to meet the evaluated cross section needs of both AEC and the Department of Defense (DoD), since DoD, through the Defense Atomic Support Agency (DASA) had extensive need for shielding cross sections and had supported considerable work in cross-section acquisition and evaluation.

In addition, a two-way translation system from Aldermaston to ENDF format was recommended. The Aldermaston file[2] represented an important accumulation of data which was available in a format used by much of the European Community and some United States laboratories.

Through the next several years, the work of the Subcommittee bore fruit and contributed much to the CSEWG effort. Its character solidified and working relationships with the other CSEWG Subcommittees evolved.

EARLY ACCOMPLISHMENTS OF THE SHIELDING SUBCOMMITTEE

Formats for Shielding Data

A report issued in 1967[1] proposed extensions of the ENDF format specifications to include data of interest for shielding calculations for reactor and other applications. Photon interaction and production processes were the primary consideration. This first attempt served as a useful starting point and provided experience to Subcommittee members. A revised set of formats and procedures was later adopted in 1971[3] and remain, with a few minor modifications, in effect to date.

Translations to ENDF Format

Work also began on translating existing evaluated data files into the neutron and photon cross section format of the ENDF/B system. Special purpose codes[4] were used in 1969 to translate data sets[5] in extended UK format to data sets[6] in the 1967 ENDF format[1] for neutron and gamma-ray-production. These were later translated[7] into the revised ENDF formats and served as useful reference sets for testing manipulation, checking, and processing codes.

A general purpose code was written[8] and used in 1970 to translate neutron cross sections in the then current version of the UKAEA library. Evaluated photon interaction cross sections[9,10] were made available[11] in 1970 ENDF format.

Development of Checking and Handling Codes

Computer codes to check the physical realism of photon production data were written[12,13] and used to test data in the original format in 1970 and in the revised format in 1971. In the same year, a special code for editing[14] data was written and the ENDF format-checking code was extended[15] to test photon production files. Extensions were also made to plot photon production files.

Data Testing Activities

The first real progress on shielding data testing began in 1971 and since then several benchmark candidates have been specified and documented. These were given Shielding Data Testing (SDT) designations and analyses of these were first done with ENDF/B-III data.

CHARACTERISTICS OF THE SHIELDING SUBCOMMITTEE

Relationship to Other CSEWG Subcommittees

After a few years of participation in the CSEWG effort, the relationship with other Subcommittees evolved into certain patterns. These were enumerated in detail in the Minutes of the December 2, 1971 Subcommittee meeting. In summary, the following relationships were stated.

1. The types of data needed for shielding applications and the formats and procedures for representing these data will remain under the aegis of the Shielding Subcommittee. Format changes and procedures proposed by the shielding group still must be submitted to the Codes and Formats Subcommittee for approval.

2. Phase I reviews of shielding evaluations will be performed under the auspices of the Data Testing Subcommittee, although many of the reviewers will be chosen from the shielding community.

3. Phase II Benchmark testing of shielding evaluations will be under the direction of the Data Testing Subcommittee. This program will be closely coordinated with the work of the Shielding Subcommittee, in particular, in the selection and specification of appropriate experiments to be used as benchmarks. A member of the Shielding Subcommittee is designated to form this coordination role and serves with joint membership on both Subcommittees.

Scope of Shielding Subcommittee Activities

In defining the scope of the shielding subcommittee, the May 1972 CSEWG Meeting Summary recognizes that "The Shielding Subcommittee is somewhat unique among the CSEWG committees in that it is not only concerned with ENDF/B procedural matters, but it also interacts strongly with data centers in addition to the National Neutron Cross Section Center (NNCSC) (e.g., the Radiation Shielding Information Center (RSIC) of Oak Ridge National Laboratory and the Photonuclear Data Center of the National Bureau of Standards) and with the shielding community in general.

In this latter role, it is attempting to provide for the data needs in several areas outside the reactor technology community although reactor shielding problems remain a central concern. Included are:

1. Fast reactor shielding problems,
2. Weapons radiation transport and shielding problems, and
3. Problems associated with heating and radiation damage due to gamma rays and charged particles produced by incident neutrons."

The Role of RSIC in Shielding Subcommittee Activities

As indicated in the preceding section, the Shielding Subcommittee has strong interaction with RSIC since its inception and RSIC has actively cooperated with CSEWG efforts to produce an adequate reference data file. It has been involved in the formatting, translation, and testing of ENDF/B data.

Clearinghouse for CSEWG Shielding Evaluation

Through the first four versions of ENDF/B, RSIC served as the clearinghouse for CSEWG "shielding" evaluations. The Center's role in this activity was to assist in the acquisition, checkout, and review of shielding cross sections in ENDF format which may ultimat ly be placed in the ENDF/B file. In this context, shielding cross sections are evaluations performed in the shielding, radiation effects, or weapons communities which are likely to have an emphasis on gamma-ray production cross sections, gamma-ray interaction cross sections, and neutron cross sections with detailed energy and angular distribution resolution in the energy range of interest for shielding. In preparation for release of a particular ENDF/B version, evaluations were received by RSIC, processed through checking codes, modified to conform to ENDF formats, and forwarded to NNCSC.

The Defense Nuclear Agency (DNA) Working Cross Section Library

The Defense Nuclear Agency (formerly DASA) established an evaluated cross section library in 1971 and supported acquisition, evaluation, and testing activities at various installations in the United States. The goal was to produce evaluated cross-section data adequate for solving the radiation transport problems encountered by DNA contractors.

The program concentrated on selected materials and the assigned evaluator was free to initiate changes to his data whenever new information was available. For that reason, the DNA Working Cross Section Library[16] is maintained at and distributed from RSIC. The library is in ENDF format and current evaluations are made a part of the official ENDF/B library whenever the latter is updated, which occurs on a two-year cycle, approximately.

Division of Magnetic Fusion Energy Evaluated Library

An evaluated data library activity, similar to the DNA Program described above, has also been established by the Energy Research and Development Agency (ERDA), Division of Magnetic Fusion Energy (DMFE). The DMFE library will also be maintained at RSIC and will serve as input to

new versions of ENDF/B. Evaluation efforts in support of the fusion area are being funded now by the ERDA Division of Physical Research.

PERFORMANCE OF THE SHIELDING SUBCOMMITTEE

Formats, Procedures, Checking, and Translation

As indicated earlier, many of the tasks originally enumerated have been completed. Formats for photon production and interaction data have been devised and checking codes written to handle them. The Shielding Subcommittee continues to recommend format changes as needs arise. The most recent examples deal with gas production data and activation and decay files which were developed in cooperation with other CSEWG Subcommittees. Version V of ENDF/B will have data in these formats.

The translation of evaluated data to ENDF format has continued with a version of the UKAEA[8] library in 1973 and translations of the Lawrence Livermore Library[17] starting in 1973.

Addition of Shielding Evaluations to ENDF/B

Through the funding of evaluation work by ERDA/DRDD (formerly DRDT) and the DNA Working Cross Section Library, substantial progress has been made toward making the ENDF/B library suitable for many radiation transport problems. The progress is tabulated in Table 1. Note that ENDF/B-IV has a substantial number of evaluations with photon production data and that the photon interaction library includes form factors[18] as well as cross sections.

Table 1. The Impact of Shielding Subcommittee Efforts on the Contents of Past Versions of ENDF/B.

ENDF/B Version	Number with γ-Production	γ-Interaction Data
I (1968)	0	No
II (1970	0	Cross Sections
III (1972)	12	Cross Sections
IV (1974)	42	Cross Sections, Form Factors

Coordinated Efforts on a National Reference Data Set

The Shielding Subcommittee served as the focal point whereby the efforts of ERDA/DRDD and DNA could coordinate toward meeting the shielding cross section needs of both agencies.

Data Testing Activities

As was mentioned earlier, CSEWG Shielding Benchmarks were first proposed in 1971. The current list of benchmarks is listed in Table 2. Note that SDT6 and SDT7 have been replaced by SB2 and SB3, respectively,

which contains descriptions of additional data. The "SB" designation is the new identification to be given to CSEWG shielding benchmarks. Some of those were used to analyze ENDF/B-III and provided input for changes to ENDF/B-IV. A comparison of results of analyzing these experiments with both ENDF/B-III and -IV data is given in Ref. 19.

In 1975, the Shielding Subcommittee proposed Formats for CSEWG Shielding Benchmark Measurements and Calculations, paving the way for the more consistent description of data testing benchmarks.

Table 2. Summary of the CSEWG Shielding Data Testing Benchmarks

Benchmark Description	Description
SDT1 thru SDT5	Broomstick Total Cross Section Tests for Fe, O, N, Na, and Stainless Steel (ORNL-3876 thru -3871)
SDT6 (now SB2)	Photon Spectra from Thermal Neutron Capture for Various Materials (ORNL-3957, SB2 in ORNL-5203)
SDT7 (now SB3)	Photon Spectra from Fast Neutron Interactions for Various Materials (ORNL-3974, SB3 in ORNL-5204)
SDT8	ZPPR/FTR-2 Shield Experiment (LASL)
SDT9	FFTF Radial Shield Mockup (AI-AEC-13048)
SDT10	LLL Pulsed Spheres (UCID-16372)
SDT11	ORNL Experiment for Neutron Transport Through Fe and Stainless Steel (ORNL-TM-4222)
SDT12	ORNL Experiment for Neutron Transport Through Sodium (ORNL-TM-4223)

FUTURE DIRECTIONS FOR THE SHIELDING SUBCOMMITTEE

The Shielding Subcommittee will continue to cooperate with other CSEWG Subcommittees. New areas of interest are likely to develop due to the needs of the community performing fusion neutronics studies. Gas production, activation and subsequent decay data, and other types of data will become more prevalent, and these will require cooperation with the new CSEWG Special Applications File Subcommittee.

In addition, the impact of uncertainty information on ENDF/B files and the importance of sensitivity studies will occupy the future attention of the Subcommittee. Sensitivity coefficients for selected experiments have been provided to aid in preparing ENDF/B-V evaluations.

The Subcommittee should puruse the data testing area more vigorously and should encourage funding agents, research laboratories, and

private industry to pool resources to satisfy the data testing requirements for light water reactor shielding, fast reactor shielding, fusion neutronics, and other disciplines.

The Subcommittee should also establish closer communication with the shielding scientists throughout the world to foster the mutual exchange of shielding cross-section data and benchmark technology.

REFERENCES

1. D. J. Dudziak, Compiler, ENDF/B Format Requirements for Shielding Applications, LA-3801 (ENDF III) (1967).

2. K. Parker, The Aldermaston Nuclear Data Library as at May 1963, AWRE 0-70/63 (1963).

3. D. J. Dudziak, Compiler, ENDF Formats and Procedures for Photon Production and Interaction Data, LA-4549 (ENDF-102, Rev., Vol. II) (1971).

4. D. J. Dudziak and J. M. Cook, LUTE and LATEX, Special-Purpose Codes to Translate from Extended-UK to ENDF/B Format, NE-3383-102-69U (ENDF-128), University of Virginia (1969).

5. M. K. Drake, J. D. Garrison, and M. S. Allen, Neutron and Gamma-Ray Production Cross Sections for Sodium, Magnesium, Chlorine, Potassium, and Calcium, GA-7829, Vols. I to VI (1967).

6. D. J. Dudziak, Translation to ENDF/B and "Physics" Checking of Cross Sections for Shielding, DASA-2379 (ENDF-130) (1969).

7. R. W. Roussin, S. K. Penny, V. A. Singletary, and J. B. Wright, Preparation of Data Sets in ENDF Format for Na, Mg, Cl, and K for Use in Shielding Calculation, ORNL-TM-3429 (ENDF-151) (1971).

8. R. Q. Wright, S. N. Cramer, and D. C. Irving, UKE-A Computer Code for Translating Neutron Cross Section Data from the UKAEA Nuclear Data Format to the Evaluated Nuclear Data File Format, ORNL-TM-2880 (ENDF-134) (1970). Updated report ORNL-TM-2880 (Rev.) (ENDF-134R) (1973).

9. W. H. McMaster, N. K. DelGrande, J. H. Mallett, N. E. Scofield, R. Cahill, and J. H. Hubbell, Compilation of X-Ray Cross Sections, UCRL-50174 (1967).

10. E. F. Plechaty and J. R. Terrall, Photon Cross Sections 1 keV to 100 MeV, UCRL-50400, Vol. VI (1968).

11. Evaluated Photon Interaction Cross Sections in ENDF Format; available from the Radiation Shielding Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, as DLC-7/HPICE.

12. D. J. Dudziak, PHOXE: A FORTRAN-IV Code to Check Format Syntax, Consistency, and Physical Realism of ENDF/B Photon Production Data, LA-4506-MS (ENDF-140) (1970).

13. D. J. Dudziak and J. M. Romero, VIXEN: A Code to Check Physical Consistency of Photon-Production Data in Revised ENDF Format, LA-4739 (ENDF-155) (1971).

14. C. L. Thompson, J. R. Stockton, L. M. Petrie, R. Q. Wright, and S. K. Penny, EDITOR, A Processing Code for ENDF/B Format Data, ORNL-TM-3266 (ENDF-142) (1971).

15. J. H. Lucius, R. Q. Wright, and S. K. Penny, Extension of the Program CHECKER, ORNL-TM-3395 (1971).

16. R. W. Roussin, Defense Nuclear Agency Working Cross Section Library: Description and Contents, ORNL-RSIC-34, Vol. I (Revised 1973).

17. R. J. Howerton, The LLL Evaluated Nuclear Data Library (ENDL): Translation of the ENDL Neutron-Induced Interaction Data Into the ENDF/B Format, UCRL-50400, Vol. 15, Part C (1976).

18. J. H. Hubbell, Wm. J. Veigele, E. A. Briggs, R. T. Brown, D. T. Cromer, and R. J. Howerton, Atomic Form Factors, Incoherent Scattering Functions, and Photon Scattering Cross Sections, J. Phys. Chem. Ref. Data 4, 471 (1975).

19. E. M. Bohn, R. Maerker, B. A. Magurno, F. J. McCrosson, and R. E. Schenter, Benchmark Testing of ENDF/B-IV, ENDF-230, Vol. I (1976).